Technology Strategy in the Solar and Wind Renewable Energy Industries

Yu-Kuang Lin [1], Steve Griffiths[2], I-Tsung Tsai[3], Toufic Mezher[4]

Masdar Institute of Science and Technology, Abu Dhabi, UAE

Institute Center for Smart and Sustainable Systems (iSmart)

[1]linyukum@hotmail.com; [2]sgriffiths@masdar.ac.ae; [3]itsai@masdar.ac.ae; [3]tmezher@masdar.ac.ae

Abstract

The renewable energy industry has been transformed enormously in the past decade especially after many countries started adopting incentives and mechanisms to increase renewable energy technologies deployment, especially in solar and wind. This has created an intense competitive environment among companies at the global level. This paper will look into the different technology strategies that solar and wind energy companies are adopting to stay competitive in terms of creating value, capturing value, and delivering value. In addition, both internal and external factors that drive their success are identified. Five case studies of solar and wind companies are analysed in order to understand their technology strategies. Based on this, effective technology strategies to create, capture, and deliver value in the solar and wind renewable industries were identified.

Keywords

Technology Strategy; Value Creation; Value Capture; Value Delivery; Solar; Wind; Renewables

Introduction

Renewable energy technologies deployment varies in terms of technology maturity and economic feasibility. For example, wind technology is becoming more economical and less dependant on government incentives. Other technologies, such as solar, have not yet reached maturity and grid parity compared to conventional energy sources. Public policies for deployment of renewable energy are being introduced in many countries in order to make them cost competitive with conventional energy technologies. This has encouraged many new companies to enter this emerging industry, especially from China. Technology strategy will play an important role in the competitiveness of both existing and new companies. They need to be able to create, capture, and deliver value for their products in order to survive in the market of renewable energy.

The renewable energy industry has grown quickly and therefore has experienced rapidly evolving market dynamics. For instance, First Solar, the biggest PV module manufacturers in the world in 2009, was surpassed by Suntech, a Chinese low cost crystalline silicon module manufacturer. What was wrong with First Solar's technology strategies? What was the secret for Suntech to be faster than any other competitors to create, capture and deliver value? Solyndra, founded in California in 2005, is a cylindrical CIGS thin-film solar module manufacturer and claimed bankrupt on September 1, 2011. What cause Solydra to fail?

In the wind industry, Chinese low cost wind turbine manufacturers including Sinovel, Goldwind, and Dongfang Electric rose quickly. However, Vestas, the world's largest wind turbine manufacturer, was able to retain its throne in the wind industry for a very long time. What technology strategies did Vestas adopt? Will Suzlon, the low cost wind leader in India, be able to capture value in China given its cost advantage?

Although technology strategy analysis has been carried out in many industries (Liang and Chow, 1997; Hipkin, 2004; Anders, 1999; and Coconete et al., 2004), there is still a gap in the literature related to technology strategies in solar and wind industries. This paper will attempt to close this gap and try to understand how solar and wind companies create, capture and deliver value in their technology strategies to stay competitive.

The paper starts by looking at the theoretical background and framework of technology strategy, as well as the overview and barriers to deployment of solar and wind technologies are investigated. Then the methodology is discussed, followed by five case studies of companies:First Solar, Suntech Power, Solyndra, Vestas, and Suzlon. Finally, the appropriate technology strategies are summarized.

Background

Technology Strategy

The "technology strategy" concept has been described by several authors. Rieck and Dickson (1993) defined it as the process of achieving corporate objectives of a firm through the use of technological resources. A similar view was presented by Ford and Saren (1996) that technology strategy is regarded as the development of corporate policies addressing the acquisition, management, and exploitation of the firm's technological assets. Furthermore, Burgelman and Rosenbloom (1989) described technology strategy as a process that emerges from organizational capabilities, shaped by four environmental forces: strategic behavior, technology evolution, organizational and industry contexts, and tempered by experience. Harrison and Samson (2002) further thought that technology strategy referred to the technological choices made by the firm. All these factors and points of view described above help firms to think about how to create, capture and deliver values to their customers through technology strategy.

From another perspective, the ultimate goal of profit-making companies is to maximize shareholder value because shareholders provide risk capital, a capital that cannot be recovered if a company fails and goes bankrupt, and they are also the legal owners of the companies (Hill et al., 2008). Maximizing shareholder value can be achieved by competitive advantage. In order to gain competitive advantage, companies must outperform their rivals through formulating and implementing strategies at corporate, business, and functional levels. For a technology intensive industry or high-tech industry, technology strategy is the vital source of all these types of competitive advantage (Ford, 1988). A technology strategy can also serve as an approach for a firm to achieve a new competitive advantage through using technology, or to defend an existing technology-oriented competitive advantage against erosion (Shane, 2009). Competitive advantage results in value creation which can further lead to superior profitability (Scott, 1995), but under the condition that the company successfully captures and delivers the values (Jacobides et al., 2006). By looking at how a company creates, captures and delivers values, we actually take into account the whole process from formulating strategies to implementing strategies. In the following sections, we will focus on how technology strategy can help a company achieve competitive advantage over competitors and thus create, capture and deliver values to achieve superior profitability (see FIG. 1).

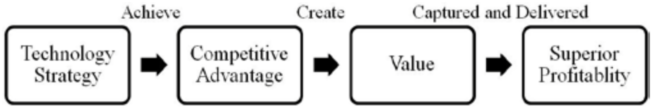

FIG. 1 RELATIONSHIP BETWEEN TECHNOLOGY STRATEGY AND SUPERIOR PROFITABILITY

1) *Value Creation*

There are various definitions of "value". Classical economists regard value as labor expended in a product, while marginalists regard it as marginal utility and neoclassical marginalists as price determination. Porter (1998) defines value as "the amount buyers are willing to pay for what a firm provides them". An alternative definition proposed by Pitelis (2009) describes value as the "perceived worthiness of a subject matter to a socio-economic agent that is exposed to and/or can make use of the subject matter in question." The advantage of this definition is that it takes "subject matters" into consideration which does not rely on "willingness to pay."

Value can be created from individuals, organizations and society (Lepak et al., 2007). We focus our discussion on organizations level of firms. At firm level, Pitelis (2009) integrated previous literature and claimed that technology and innovativeness, human resources and their services, unit costs economies/returns to scale and firm infrastructure and strategy are the four generic determinants of value creation. All other factors affect value creation through these four determinants and each determinant interacts with one other. We will base our discussion on the above model and further identify some important sub-factors of these four determinants.

The technology S-curve can shed some light on the relative payoff of investment in competing technologies and when and why some technologies overtake others in the race for dominance (Schilling and Esmundo, 2009). The S-curve plots product or process performance against effort expended. For example, FIG. 2 traces out the path of development of wind energy performance with each successive point on the curve representing an improvement in performance. It can be seen from the figure that progress is marginal at the beginning for quite some time, and then increases drastically. As the technological limits approach, the return

diminishes. If the limit for an S-curve can be predicted, then the S-curve can yield valuable insights. It should be noted that technological progress is not plotted against time. This is because it refers to the amount of effort that leads to progress rather than time.

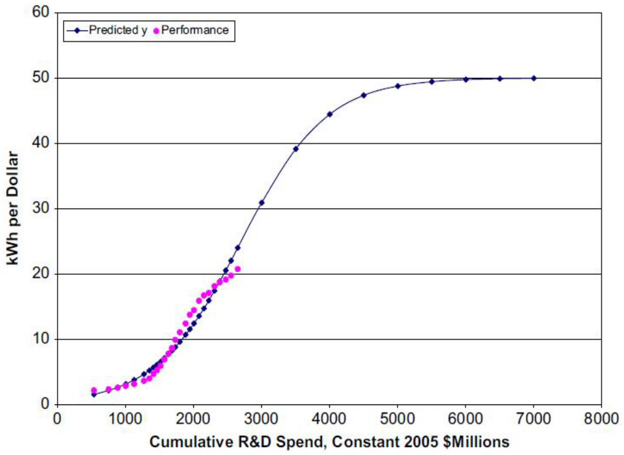

FIG. 2 WIND ENERGY PERFORMANCE S-CURVE. SOURCE: (Schilling and Esmundo, 2009)

A single technology seldom meets all customers' needs, which is why S-curves always come in pairs, which means that a new technology often comes to compete with an established technology just as the latter approaches the peak of refined performance. It can be perceived that there is an offsetbetween the pair of S-curves for the technologies. This offset represents discontinuity, which is the point at which the new technology replaces the established technology. In order to manage a technological discontinuity, firms may need to venture into new areas where they lack skills and abandon a technology even if the technology has just entered the most productive phase of its S-curve.

Managing resources to adopt disruptive technologies and transit to a new technology S-curve through integrative capabilities (Henderson, 1993), ambidextrous internal processes (Tushman and Anderson, 1986), complementary assets (Tripsas, 1997) or architectural innovation (Henderson and Clark, 1990) is also worthy of attention (Christensen, 1997).

The different industry life cycles, evolution of markets and diffusion of innovation are also important dimensions of technology and innovativeness to examine. Diffusion is the "process by which an innovation is communicated through certain channels over time among the members of a social system" (Rogers, 1995). To understand the acceptance of new products, we can refer to the Technology Adoption Life Cycle model, which divides customers into five groups: innovators, early adopters, early majority, late majority and laggards (Moore, 2002). The model describes the market penetration of any new technology product in terms of progression in the types of consumers it attracts throughout its useful life.

In order to develop a high-tech market, we first need to focus on the innovators growing the market, and then move on to the early adopters and so on. In this way, companies can use the "captured" group as a reference base for the next group. It is also important to maintain momentum in order to create a bandwagon effect that makes it natural for the next group to want to buy in. The High-Tech Marketing Model is essentially a reflection of a smooth unfolding through all the stages of the Technology Adoption Life Cycle. Based on experience, Foster (1988) argued that the Technology Adoption Life Cycle should be revised as FIG. 3. The components are unchanged, but there are gaps between any two psychographic groups, symbolizing the dissociation between the two groups. Any group will have difficulties accepting a new product if it is presented in the same way as it was to the group to its immediate left. Two of the gaps are relatively minor, which may be referred to as cracks.

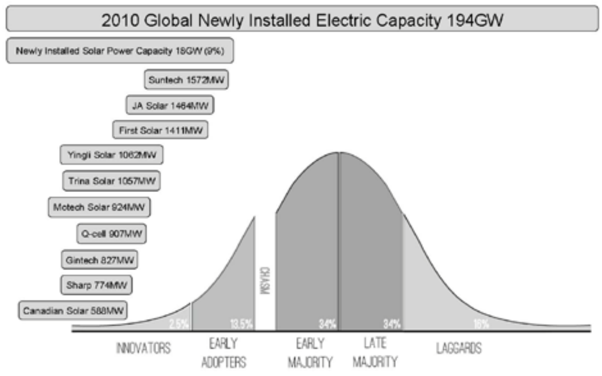

FIG. 3 REVISED TECHNOLOGY ADOPTION LIFE CYCLE OF SOLAR INDUSTRY

The first crack is between innovators and early adopters. The key to winning over the early adopters is to show that the new technology enables some strategic leap forward by single compelling application, which captures the power and value of the new product.

The other crack is between early majority and late

majority. The early majority is willing and able to become technologically competent, where necessary; the late majority, much less so. This means that when a product reaches this point in the market development, it must be made increasingly easier to adopt in order to continue being successful.

As Foster (1988) mentioned, the biggest challenge is in crossing the chasm between early adopters and early majority. Early adopters want to be pioneers in implementing a new technology in their industry and expect to gain radical competitive advantages, while early majority just want to improve (not replace) existing operations by integrating new technologies. Because of different objectives, early adopters do not make good references for the early majority. The result is that an early majority customer will only refer to another member of the early majority.

Market penetration and crossing the chasm between each customer group are the essential parts of the Revised Technology Adoption Life Cycle. In order to cross the chasm between early adopters and early majority, companies have to be patient and familiar with their particular business. They also need to show up at industry-specific conferences and trade shows, be mentioned in articles in the magazines, be installed in other companies in early majority's industry, have developed applications for the product, have partnerships and alliances with other vendors, and have earned a reputation for quality and service.

2) Value Capture

Lepak et al. (2007) claimed that competition and isolating mechanisms are the two key concepts that determine which party captures the value that is created. MacDonald (2004) deduced some key concepts from game theory that the possibility of imitation is thought to influence value appropriation by stimulating competition, and bargaining is also critical in determining how much value a firm can appropriate. Porter's five forces analysis (Porter, 2000; Porter, 2008) further claims that the competitive intensity in a specific industry is determined by three forces from horizontal competition and two from vertical competition. Horizontal competition comprises of threat of substitute products, the threat of established rivals, and the threat of new entrants. Vertical competition comprises of the bargaining power of suppliers and the bargaining power of customers. Complementary products and the government are considered the sixth force as an extension to Porter's five forces analysis. Lavie (2007) claims that the firm's appropriation capacity depends not only on its bargaining power relative to partners but also on the competitive tension with its partners and among partners in its alliance portfolio. He further claimed that the firm's market performance is enhanced by the multilateral competition among partners and that the firm's formation of alliances with a partner's competitors can reduce its dependence on any given partner.

According to the firm's view (based on resource), resources may serve as isolating mechanisms and also limit the competition if they are rare, inimitable, non-substitutable and valuable (Barney, 1991). Legal barriers to imitation include patents, copyrights, and trademarks (Shane, 2009). However, most non-legal barriers to imitation are more effective than legal barriers. Drawn from the conclusion of Cohen et al. (2000), lead time, secrecy, complementary assets in manufacturing and complementary assets in sales and service are believed to be more effective at protecting new products and processes. Here, complementary assets refer to upstream or downstream assets that are used to develop, produce, or distribute an innovative new product or service. Henderson (1990) deduced that firms which typically have both a unique product and tightly held complementary assets are the ones that succeed in making a great deal of money from innovation. Firms who only have a unique product should build the new complementary assets while firms who only have complementary assets should try to capture values from new ideas. For those companies that have more scale, economies of scale is another weapon to deter imitation. Moreover, the learning curve can effectively deter imitation for industries in which values are mostly generated from tacit knowledge. First movers can exploit switching costs to deter imitation. Establishing a reputation also serves to deter imitation and gain first mover's advantage through branding (Kardes et al., 1993).

Sometimes it is wiser to be an imitator. Teece (1986) proposed a model that imitators are more successful than innovators when innovations are easy to imitate, a dominant design has emerged in an industry, and imitators control the key

complementary assets in the industry. Hoppe (2000) also claimed that latecomer advantages may exist in the strategic adoption of new technology under uncertainty because of informational spillovers. Wu et al. (2010) raised a point that latecomer firms can create and capture value from disruptive technologies in emerging economies through secondary business-model innovation by changing the existing competition basis and tailoring the original business model to fit price-sensitive mass customers. Latecomer firms should also fully utilize the complementary assets of strategic partners to overcome their latecomer disadvantages and build a unique value network embedded within the emerging economies context. Wu et al. (2010) also compared the first mover's advantages and latecomers' advantage thoroughly which shed some light on the strategy that emerging latecomer firms should adopt. In energy production, a big barrier is that first movers have big risks because complimentary assets including grid, storage, charging station are not in place.

Jacobides (2006) mentioned that other than capturing value from innovative efforts through fending off imitators and achieving superior profitability, firms can also benefit from investing in complementary assets that will appreciate.

According to Chatain and Zemsky (2011), frictions, which source from search costs, transaction costs and barriers to trade, give rise to incomplete linkages in the industry value chain. More frictions are preferred by less efficient suppliers as they provide them with protection from competition. Chatain (2011) further confirmed this concept with the argument that expertise advantage, relative to the set of relevant competitors, matters more to value capture than expertise advantage relative to all competitors in the market. Furthermore, prices become implicitly more dispersed as frictions increase. The extent of frictions in the product market is inversely related to value creation, but has a U-shaped relationship with value capture. Finally, changes of leadership are more likely in industries with more frictions.

Lin et al. (2006) suggested that for firms with extremely high-technology stocks, the most effective method is to diversify their technology resources to a wide spectrum of technology fields, while focusing on a small number of core technologies within their core technology fields. On the other hand, a firm without very high-technology stocks should concentrate its research and development (R&D) resources on a specific technology field, while focusing on a small number of core technologies within the core technology field. Lastly, a firm with limited technology stocks should concentrate its R&D resources on a specific technology field, while concentrating on several emerging technologies within its core technology field.

Morrow et al. (2007) statistically showed that valuable and difficult-to-imitate strategic actions contribute the most to organizational recovery. Acquiring new resources through mergers or acquisitions, instead of alliances or joint ventures, also has a positive effect on investors' expectations. Taking actions that are not valuable and difficult-to-imitate either have no effect on performance or may lead to further performance declines.

Activities that lower buyers' costs or increase buyers' performance through products and services are the main contributors to the creation of value by differentiation along every step of the value chain. Drivers of product differentiation, and hence sources of value creation, include: policy choices (what activities to perform and how), linkages (within the value chain or with suppliers and channels), timing (of activities), location, sharing of activities among business units, learning, integration, scale and institutional factors (Porter, 1998). Examining the value chain will help identify where most of the value is created and decide how to compete with other firms to capture value and the ownership of parts of the value chain through vertical integration. There are four factors to consider when deciding whether a firm should use contractual or vertically integrated modes of doing business; these factors include: the industry, the nature of core technology, the type of firm, and the strategic factors (Shane 2009).

Winning a standards war could lead to market dominance between incompatible technologies and maximize the captured value. Shapiro and Varian (1999) mentioned seven key assets to wage a standards war, which include: control over an installed base of users, intellectual property rights, ability to innovate, first-mover advantages, manufacturing capabilities, strength in complements, and brand name and reputation.

3) *Value Delivery*

To effectively deliver value, Eisenhardt and Sull (2001) proposed that current strategy should be formulated as simple rules in fast changing business environment. Companies should focus on key processes and improvise as simple rules, including: how-to rules, boundary rules, priority rules, timing rules, and exit rules. Brown and Eisenhardt (1997) claimed that regenerating is an effective short-term strategy while probing is an effective long-term growth strategy. The best practices for probing include a wide variety of low-cost probes, managing number of probes, not just types, and creating identity of company. As for regenerating, the best practices involve the coupling of comprehensive and continuous redefinition of the products and services a firm provides with creating and using new resources and capabilities (2001). Eisenhardt further elaborates the timing rules as "Time Pacing." Time pacing refers to "creating new products or services, launching new businesses, or entering new markets according to the calendar, and creating a predictable rhythm for change in a company." Time pacing is also a timeline comprising current strategy as simple rules, short-term strategy as regenerating and long-term strategy as probing. In contrast, event pacing is a reactive strategy, responding whenever an event happens. Time pacing was also critical for managers to decide how often to change. Firms can implement time pacing through tracking performance by time-based measures, managing and exploiting transitions, and managing rhythms (Eisenhardt and Brown (1998). Managing transitions effectively requires companies to have clear, choreographed processes.

Eisenhardt (1989) also argued that rapid decision making in fast moving, and ambiguous environments is critical to competitive advantage, value delivery as well as mitigating overload. From a multi-case study of computer firms, Eisenhardt concluded the best practices for speeding decision making are considering more simultaneous alternatives, use of experienced counselors and use of active conflict resolution. Faster decision making results in higher performance, while slower decision making generally results in failure to make critical decisions.

In addition, Eisenhardt et al. (2009) stressed that having a good fight would help a company make high-stake decisions. The key is to mitigate interpersonal conflict by focusing on the facts, multiplying the alternatives, creating common goals, using humor, balancing the power structure, and seeking consensus with qualification.

Reppening and Sterman (2001) advised that it should be known beforehand when working towards smarter yields things will be "worse before better." In order to get unstuck, companies should complement "bottom up" with "top down," focus on eliminating defects with the best cost/benefit ratio, respond to a screw-up as though it were a capability problem and have a clear strategy and live by it.

Technology Strategy Analysis Framework

As shown in FIG. 4, on the basis of prior studies, we propose a technology strategy analysis framework with three dimensions, value creation, value capture and value delivery. Each dimension contains several important elements derived from the literature, in order for us to analyse the selected case studies.

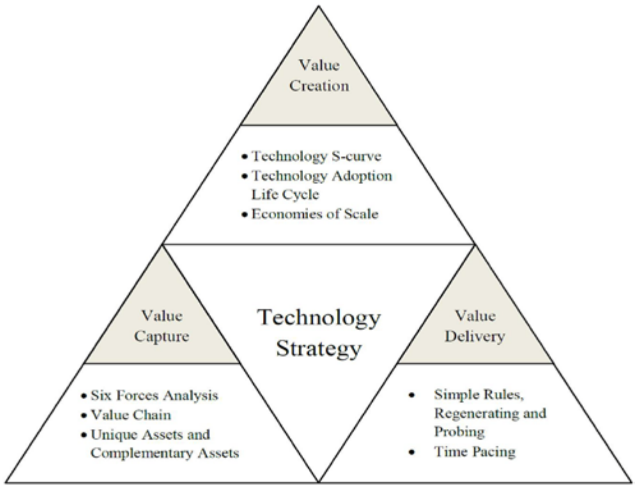

FIG. 4 TECHNOLOGY STRATEGY ANALYSIS FRAMEWORK

Value Creation

We look at the company's technology S-curve to see how the technology forecast creates value. We can gain insight into how much value a company has to create given the different stages of technology adoption life cycle. A How to leverage economies of scale is another important issue in creating value.

Value Capture

Starting with six forces analysis can give us a clear idea of how competitive an industry is and how to

capture value in the industry given the existing forces. Value Chain analysis can identify whether to adopt upstream or downstream integration. Utilizing unique assets and complementary assets also results in value capture.

Value Delivery

Simple rules, regenerating and probing directly determine current, short-term and long-term value delivery, while time pacing determines how fast a company is able to deliver value and how companies are able to make transitions.

Solar Industry

According to the Renewable Energy Policy Network for the 21st Century (REN21)[1] reports, an estimated 20 GW solar photovoltaic (PV) capacity was and the average 5-year growth rate exceeded 60% during 2012, which is the fastest among all renewable technologies. The existing global total solar PV capacity was about 100 GW at the end of 2012, which is more than 20 times higher than in 2005. The EU accounted for 17 GW about 57% of the newly installed capacity, 7.6 GW of which was added by Germany.

Given it's rapidly evolving dynamics, the solar industry has experienced many changes in the past few year. In 2010, Suntech Power had the highest market share among solar PV module manufactures with a shareof 7%, replacing First Solar which was the leader in 2009. By 2012, Yingli Green Energy of China had displaced Suntech and had achieved nearly a 7% market share. For module manufacturing, the trend toward shifting to Asia continued in 2012, with Asia accounting for 86% of total production. Government subsidies, which played an important role in PV market growth, were cut back especially in EU, the main source of demand.

Next, Porter's five forces are analysed in addition to the complementary products and government policies in order to gain insights to the future profitability of solar industry and the overall competitive intensity in 2011 compared with early 2000s.

Risk of Entry by Potential Competitors

The risk of entry by potential competitors is considered low if the entry barriers are high. The entry barriers are high when economies of scale arise, brand loyalty exists, established companies have an absolute cost advantage, customer switching costs are high, and government regulation is not favorable for new entrants. Brand loyalty in the solar industry is relatively significant because solar projects are awarded to companies that utilize technologies of well established and have proven suppliers. However, in the early 2000s, although government regulations and subsidies were not yet well established, which was not favorable for new entrants, the entry barriers were low as the established companies had not yet enjoyed absolute cost advantages. Before the global financial crisis in 2008, although the government incentives became very favorable for new entrants, the entry barriers grew higher and higher as a result of significant economies of scale, and absolute cost advantages enjoyed by established companies. After the financial crisis, the entry barriers became even higher due to the massive reductions of government incentives. Overall, the entry barriers were very low in the early 2000s and entry barriers are much higher nowadays. Nevertheless, new firms still entered since they perceived that the benefits outweighed the substantial costs of entry.

Intensity of Rivalry Among Established Companies

The intensity of rivalry, competing price per watt, conversion efficiency, production capacity and reliability, increased in the decade leading to 2010. Some of the top 10 PV manufacturers in 2010 were very small in 2006. Although growing demand moderates competition, given the increasing number of PV module manufacturers and high exit barriers, the intensity of rivalry remained high. Furthermore, Chinese solar companies were supported by their government which gave them considerable competitive advantage via trade practices considered unfair by European and US solar companies.

The Bargaining Power of Buyers

Most of the buyers who purchase solar panels are project developers who purchase in large quantities. They are large and few in number. However, before 2009, the demand exceeded supply so that buyers did not have much bargaining power. With the dramatic expansion of solar module production capacity, capacity outstripped demand by 2010, which resulted in increased bargaining power for buyers.

The Bargaining Power of Suppliers

The solar industry heavily depends on crystalline

[1] http://www.ren21.net

silicon – the main materials of most solar panels. Therefore, the price of crystalline silicon highly correlates with the price of solar modules. During 2008 and the first half of 2009, shortage of crystalline silicon supply resulted in the soaring price of crystalline silicon. Therefore, some module manufacturers signed long term contracts with silicon plants, and some adopted upstream vertical integration strategy. As increased numbers of new crystalline silicon plants began production, the bargaining power of suppliers decreased and the costs of polysilicon went down nearly 55% in 2009, according to Solarbuzz reports.

Substitute Products

Solar energy has many substitutes. PV plants can provide daytime peak load power but this can substituted by fossil energy plants. Concentrated solar power (CSP) plants with storage can provide base load power and be substituted by nuclear, coal, natural gas plant, hydro dams, etc. Natural gas is a major substitute and threatens solar energy deployment, because natural gas, particularly derived from shale, is more abundant than previously thought and is a key substitute to consider given that it is relatively cleaner burning than coal. Electricity utility quota obligation policies can mitigate the threat of those substitutes in short term. In the long run, however, the solar industry still has to find a way to attain grid parity. A major issue with solar energy is that it is an industry taking on established technologies that are part of an existing infrastructure. Energy is just a commodity and making it difficult to be differentiated.

Complementary Products and the Government

In the solar industry, complementary products are maintenance services, energy storage facilities, power grid, etc. The growth of solar energy will drive the growth of those complementary products. Favorable incentives from government policies is a key force driving the the solar energy industry. Popular policies include feed-in tariffs (FIT), capital subsidies, and renewable portfolio standards (RPS). FIT policy requires utilities to buy renewable power at government-mandated rates which is usually above market prices. FIT currently is the strongest driver for solar industry growth. A good example for capital subsidies is that U.S. launched the Investment Tax Credit (ITC) program to subsidize 30 percent capital for renewable power producers. RPS requires utilities to purchase a prescribed amount of renewable energy.

In conclusion, the solar industry has changed dramatically within this decade from a less competitive and low entry barrier environment to a highly competitive and high entry barrier environment. Companies who want to capture value in this highly competitive environment should redefine their business to avoid buyer power and price competition through expanding their buyer bases globally, focusing on countries with high government subsidies, or integrating downstream into project development. Investing in disruptive solar technologies would be another effective strategy to win the price competition by creating a new cost curve. Collaboration either through joint ventures, outsourcing agreements, product licensings, or cooperation research is a short cut for new competitors to gain technology and market access (Hamel et al., 1989). Alliances between Asian companies and Western companies seem to work against Western rivals, especially in Chinese market, where local companies have government support but have less technology access.

We also need to look at which stage of the technology adoption life cycle the solar industry is in. Instead of existing energy capacity, we define the market as the newly installed electric capacity because this can precisely reflect the trending of market opportunity. According to REN21 reports, the global newly installed electric capacity in 2012 is 283 GW, with solar power accounting for 9% about 18 GW, which means the solar industry currently hasn't crossed the chasm in terms of newly installed electric capacity (see FIG. 3). In order to cross the chasm, solar companies should keep driving down the costs to reach grid parity, because cost-related issues (specifically energy prices) are the most important drivers of energy innovation according to Anadon et al. (2011). Grid parity is already achieved in some locations such as Japan and Hawaii. In markets with very high energy costs, solar power can be cost competitive. Furthermore, solar companies should be able to prove their credibility through past successful projects, show up at the energy conferences and trade shows, be mentioned in technical journals and magazines, have developed applications for the product, have partnerships and alliances with other vendors, etc. Other challenges to cross the chasm include the intermittency of solar power, lack of infrastructure to support less centralized generation, and less mature storage technology (Hallmon et al., 2010). These challenges also show that there are no dominant standards in terms of decentralized generation and storage

technology yet, which could be barriers to deployment but at the same time opportunities for tipping the market.

Wind Industry

During 2012, 45 GW wind power capacity was added and the average growth rate was 25% over a 5 year period according to REN21 reports . The existing global total wind power capacity is about 283 GW which is nearly six times higher than in 2004. China and the US each accounted for 13 GW of the newly installed capacity. Germany., was a distant second place with 2.4 GW. The offshore wind industry grew, increasing by 1.3 GW to 5.4 GW at the end of 2012. In order to reduce costs, including infrastructure such as substations or grid connection points, as well as licensing and permitting costs, the size of individual wind projects is increasing.

In 2010, Vestas of Denmark remained its number one market share throne in the wind turbine marketwhile GE Wind was surpassed by Sinovel of China in 2010 and settled in the second place. In 2012, however, GE had overtaken Vestas in market share and Sinoval had fallen out of the top 5 wind turbine manufacturers by market share.

In 2008, the U.S. market was prosperous thanks to Investment Tax Credit, Production Tax Credit (PTC) and Renewable Portfolio Standard. The Chinese market was fueled by feed-in tariffs. Australian, Japanese and Indian markets were also supported by the government. However,the future of the wind industry remains unclear because of the removal of PTC in U.S. market, the sovereign crises in Europe and intense competition in Asia.

We again performed the six forces analysis in order to gain an insight of the future profitability of wind industry and the overall competitive intensity in 2011 compared with early 2000s.

Risk of Entry by Potential Competitors

The switching costs in wind industry are always high due to high costs of wind power systems and installation. Brand loyalty in the wind industry is significant in most of the markets because customers make their purchase decisions not only by price but also by the services provided, and wind projects are also awarded to companies that are considered “bankable,” except perhaps in the Chinese wind energy market where local content is a primary factor. In the early 2000s, government regulations and subsidies in China were not yet well established, a situation that was not favorable for new entrants. In addition, established companies had enjoyed absolute cost advantages and the cost advantages from economics of scale till that moment. Combined with huge amount of start up capital from both materials and long project completion time, the entry barriers in the wind industry were considered very high. The situation changed when the Chinese government announced policy incentives and a high renewable energy capacity target, which lowered the entry barriers in the Chinese market. New firms started to enter since they perceived that the benefits outweighed the substantial costs of entry in China.

Intensity of Rivalry Among Established Companies

The intensity of rivalry has been increasing since the entrance of GE in 2003 and Siemens in 2004, both through acquisitions, and entry of Chinese players. The top 10 wind turbine manufacturers remained similar, but the rankings of Chinese wind companies has risen. Growing demand in China resulted in the establishment of a great number of Chinese wind companies such as Sinovel, Goldwind and Dongfang Electric which collectively accounted for nearly 60% of newly installed capacity in 2009 (Junfeng et al., 2010). The growth of Chinese wind companies was mainly due to the state support of the Chinese government.

The Bargaining Power of Buyers

Most of the buyers who purchase wind turbine systems purchase in large quantities but there are many buyers. Therefore, buyers don’t have much bargaining power in the wind industry.

The Bargaining Power of Suppliers

According to the BTM wind report, World Market Update 2010, published by Navigant Research[2], the number of most wind turbine component suppliers more than tripled between 2006 and 2009 and the gearboxes suppliers might have had the greatest bargaining power since there were only 28 gearboxes suppliers in the world in 2009.

Substitute Products

Wind power, among all of the renewable energy substitutes such as hydro dams or solar panels, is one of the cheapest options. However, the dramatic decline of solar module and natural gas prices in

[2] http://www.navigantresearch.com/

recent years and localized solar resources posed a great threat to the wind industry. To compete with coal and natural gas plants in the long run, the wind industry must keep driving down costs to reach grid parity and also find solutions for energy storage so that baseload power is possible.

Complementary Products and the Government

In the wind industry, complementary products are wind resources mapping, maintenance services, energy storage facilities, power grid, etc. The growth ofwind energy will also drive the growth of those complementary products. Like the solar industry, FIT is currently one of the strongest drivers for the wind industry globally, although production tax credits drive the industry in the United States.

In conclusion, the wind industry has changed over the last decade, mainly because of the rise of Chinese wind companies. Companies who want to remain competitive and keep capturing value in this highly competitive environment could reposition their businesses to either provide good quality service to avoid price competition, expand new markest to avoid strong rivals in China, or perhaps build strategic alliances with Chinese wind companies access to the market.

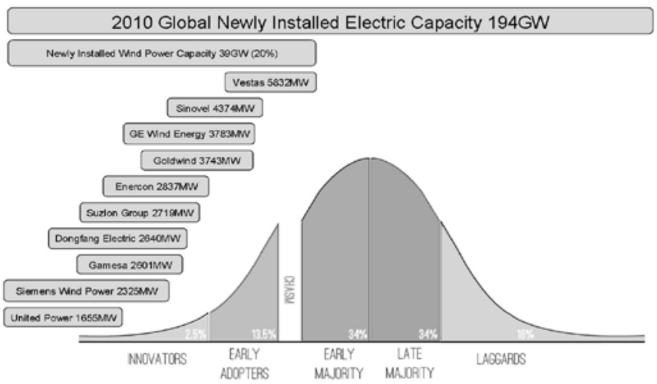

FIG. 5 REVISED TECHNOLOGY ADOPTION LIFE CYCLE OF WIND INDUSTRY

If we look at which stage of the technology adoption life cycle the wind industry is in, we might find that the wind industry had already crossed the chasm (see FIG. 5). Based on REN21, wind power accounted for 18% of the newly installed electric capacity in 2010, which was about 39 GW, and it accounted for 39% of renewable power capacity that was added in 2012 . In order to further penetrate the early majority and reach the late majority, wind companies should not only keep driving down the costs to reach grid parity, but also strive to go global, especially to where markets and policies are attractive. The wind industry faces similar challenges to the solar industry, for example, lack of infrastructure to support less centralized generation and less mature storage technology (Hallman et al., 2010). Intermittency of wind power is also another issue. More detailed analysis about the barriers to deployment of solar and wind energy is carried out in the next section.

Barriers to Deployment of Solar and Wind Energy

High Capital Cost and Slow Asset Turnover

Most large-scale power generation infrastructure costs more than 1 billion U.S. dollars and the median age of the current fleet of U.S. coal-fired power plants is 44 years.

Incumbent Advantage

New technology may have superior operating performance. However, the high cost and long life of current infrastructure gives existing energy assets a substantial cost advantage over new competing technologies.

Commodity Status of Energy

The energy system is different from information and communication technologies, which experience a rapid pace of innovation. It is difficult for energy companies to offer significant product improvements to consumers because consumers are generally indifferent about the source of the electricity that they purchase.

Reliability Premium Favors Incumbent Technologies

The energy system, especially the electricity sector, places a premium on reliability because consumers, regulators, politicians, and other stakeholders have very low tolerance for blackouts or fuel shortages.

Regulatory Environment

All aspects of the energy system are heavily regulated, especially the electric utilities. This characteristic limits the upside from taking additional technology risks, with incentives geared towards reliability and low upfront costs.

Technology Risks

Solar and wind energy projects have a great uncertainty about whether the facility can be built to specification within a given timeframe and

construction budget. The performance factors, including operating costs, efficiency, availability factor, maintenance costs and environmental issues are hard to predict.

Policy, Regulatory, and Market Uncertainties

Solar and wind energy markets are currently driven by policy incentives. As soon as the policy or regulatory changes, the market could change dramatically.

In the current situation, solar and wind companies may not be able to cross the chasm without the help of public R&D and deployment policies.

Methodology

Research Strategy

We will examine the three dimensions of technology strategy, value creation, value capture and value delivery by reviewing case studies of firms in solar and wind industries. Although the case studies become dated given the rapid pace of change in the renewables industry, they nonetheless provide a framework for exploring energy technology strategy as outlined in this paper.

We define the dependent variable as the company's performance, which may include market share, market value, and growth rate. The causal relationship of dependent variable and the three dimensions of independent variables, including value creation, value capture and value delivery, will be identified.

Case Selection and Data Collection

The research objective chosen in our study requires comparison of several cases. We will have to do controlled comparison, i.e., the comparison of "most similar" cases which, ideally, are cases that are comparable in all aspects except for the independent variable, whose variance may account for the cases having different outcomes on the dependent variable. This can be achieved by dividing a single longitudinal case into two - the "before" case and an "after" case that follows a discontinuous change in an important variable (Junfeng et al., 2010). However, even when two cases or before-after cases are not perfectly matched, process-tracing can reinforce the comparison by helping to assess whether differences, other than those in the main variable of interest, might account for the differences in outcome.

We combine several case studies based on replication logic (Yin, 2009), which is "the logic of treating a series of cases as a series of experiments with each case serving to confirm or disconfirm the inferences from previous ones." Multiple case design results in a more reliable model although design complexity is higher than a single case study.

The five firms included in the study are First Solar, Suntech, Solyndra, Vestas and Suzlon. These companies were chosen in the research for theoretical rather than statistical reasons (Glaser, 1968). They belong to either the solar or wind industry, covering the industries from various aspects, filling different theoretical categories, and providing examples of polar types. The solar companies include: First Solar, Suntech, and Solyndra, while the wind companies include: Vestas and Suzlon. It is important to emphasize on the following points:

- Suntech is a Chinese company; First Solar is an American company; Suzlon is an Indian company; Vestas is a Danish European company
- Suntech focuses on crystalline PV technology while First Solar and Solyndra focus on thin film technology
- Solyndra went bankrupt as a result of major challenges faced due to silicon PV competition from China, especially Suntech; on the other hand, First Solar was successful

Given the abundant dimensions of the five chosen companies, the result explains the general characteristics of solar and wind industries. In addition to using information about these companies gathered from the Harvard Business School, we also collected relevant data from government reports, industrial studies, trade publications, company websites, and archived data.

Case One: First Solar

First Solar[3], headquartered in Arizona and the largest thin-film module manufacturer in the world, was established in 1999 and began commercialization of its products in 2002 (Hallmon et al., 2010). Its capacity reached 2.8GW in 2012. It has the lowest PV module cost at $0.74 per watt and accumulated production surpassed 5GW in 2011 Q3 based on First Solar annual reports.

[3] http://www.firstsolar.com/

Value Creation

1) Technology S-curve

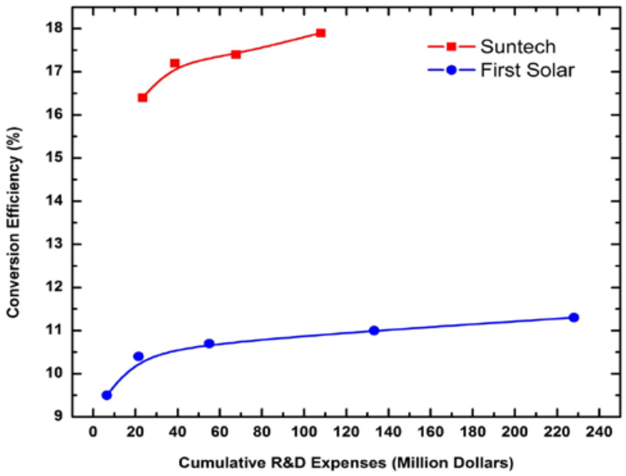

FIG. 6 SUNTECH AND FIRST SOLAR'S TECHNOLOGY S-CURVES

FIG. 6 shows the Technology S-curve of First Solar's cadmium telluride (CdTe) thin film technology. The conversion efficiency is increasing every year. However, thin film technology could have been viewed as approaching its theoretical limit since the same amount of R&D expenses makes less and less efficiency progress. The company was aware of this trend and took actions to mitigate the threat of disruption by investing in technology development and recruitment of energy elites from start-ups and research labs. Although results are still forthcoming, this might be an effective strategy to create value in the long term and be part of full value chain integration.

2) Technology Adoption Life Cycle

Thin film PV market share dropped from 25% in 2009 to 13% in 2010 based on REN21 reports and it has continued to decrease. Despite more than 26% of production growth in 2010, First Solar's market share declined from 10% in 2009 to 6% in 2010, and 15% in 2012 according to REN21 reports. Since the conversion efficiency of CdTe thin film technology is substantially lower than crystalline silicon PV technologies and the cost gap between them keep decreasing, whether First Solar will be able to lead the solar industry to cross the chasm remains a question mark if the company loses cost advantage.

3) Economies of Scale

Based on First Solar annual reports, the module cost fell from 1.4 $/W in 2006 to 0.77 $/W in 2010 as the annual production increased. We regressed annual production against module cost and found out that one MW increase in annual production decreased module cost about 0.044 cents per watt, inferring strong economies of scale at 1% significance level. The main source of cost reductions was from efficiency improvement (18-25% of cost reduction), while high throughput, spending saving, low cost location, and plant scale accounted for another 13 to 18% of cost reduction according to First Solar reports.

Value Capture

1) Six Forces Analysis

Of roughly 150 thin-film module manufacturers that existed in 2008, only about 70 were estimated to be active by early 2010, indicating less competition within thin film rivals. However, the global PV industry consisted of more than 150 solar cell and module manufacturers . For First Solar, the substitute, crystalline PV modules, started to erode its market share as costs of crystalline PV modules went down. New entrants from established semiconductor manufacturers with significant financial resources, production capacities and prestigious brand name are big threats for First Solar. First Solar buys CdTe from few mining companies. Fortunately, CdTe has no apparent other industrial use, so the risk from suppliers for First Solar is smaller than other crystalline PV companies. During 2010, EDF EN Development, Juwi Solar GmbH, and Phoenix Solar AG each accounted for 10 to 20% of First Solar's net sales. Due to the great bargaining power from these buyers, First Solar had to launch a rebate program which reduced the captured value.

2) Value Chain

Instead of beginning with creating wafers from silicon feedstock as crystalline silicon PV module manufacturers do, thin film module manufacturers start with cheap glass or aluminum substrate. For First Solar, the second step is to deposit CdTe on the substrate for the development of cells and ultimately modules. System integrators and installers then purchase modules from First Solar and integrate with balance of system (BOS) components to generate power. BOS includes inverters, wiring, circuitry, mechanical structures, labor, and all the engineering, permitting and construction (EPC) activities. Vertical integration becomes more and more popular. Yingli and Trina adopted upstream integration strategy to gain

control over ingot and wafer production due to their volatile prices. SunPower integrated downstream into developing system projects. First Solar also adopted a vertical integration strategy by acquiring system developers, Turner Renewable Energy, LLC, OptiSolar Inc. and NextLight Renewable Power, LLC to move into the U.S. market. This movement can effectively capture values in the growing U.S. energy market and mitigate the risk of subsidy cutbacks in EU.

3) Unique Assets and Complementary Assets

First Solar's unique asset was the CdTe thin film technology which reached 17.3% conversion efficiency in 2011 Q2 based on First Solar reports. At the same time, First Solar also worked on building tightly held complementary assets including automated manufacturing processes and facilities, long-term contracts with buyers, project development ability, and recycling capabilities. The technology breakthrough combined with complementary assets would keep driving down the module costs and enabling sustainable value capture.

Value Delivery

1) Simple Rules, Regenerating, and Probing

First Solar's mission statement is "to create enduring value by enabling a world powered by clean, affordable solar electricity". To achieve this target, First Solar set up several simple rules. One of them is to reduce solar electricity costs to sustainable levels through technology development, operational excellence, and scale. Following this rule has helped First Solar to drive down costs year by year. First Solar acquired system developers to move into the U.S. market based on another simple rule, using price, adaptive business models, and partnerships to expand markets. Those simple rules have proved effective in the fast changing solar industry.

2) Time Pacing

The transition from the EU market to other markets, such as the U.S. and Chinese markets, and from subsidized markets to non-subsidized markets is happening. First Solar managed U.S. market transitions through vertical integration, which was an effective strategy and the revenue from the U.S. market kept increasing. First Solar claimed to manage transitions from subsidized markets to non-subsidized markets by leveraging economies of scale. First Solar rolled its first production line in 2005 and since then, it added 2 lines in 2006, 12 lines in 2008 and 9 lines in 2010 based on First Solar reports. First Solar achieved low costs via manufacturing locations such as Malaysia. The pace slowed down as the competition intensified and the demand declined due to the global financial crisis. We could infer that First Solar adopted an event pacing strategy. As a result of slowing down, First Solar yielded its biggest market share throne to Suntech Power in 2010. In response, First Solar tried to speed up and added 12 manufacturing lines in 2011, trying to catch up with Suntech Power but in vain. Since Suntech Power planned to hold capacity at current levels in 2012 to minimize capital expenditures, First Solar also planned to have only 4 more lines in 2012. The solar industry is a fast-paced market, so event pacing strategy is not really effective to deliver value. If First Solar fails to manage the production rhythm, heading towards the fate of falling behind competition is inevitable.

Case Two: Suntech Power

Suntech Power [4] (Vietor, 2012), first incorporated as Wuxi Suntech Power in 2002, was the world's largest solar module manufacturers, producing 1572 MW in 2010. As of December 31, 2010, the average conversion efficiency rates of Suntech Power's monocrystalline and multicrystalline silicon PV cells were 17.9% and 15.9%, respectively according to Suntech annual reports.

Value Creation

1) Technology S-curve

FIG. 6 shows the Technology S-curve of Suntech Power's monocrystalline silicon PV technology. The conversion efficiency is shown increasing every year and likely to keep growing since the S-curve is going upstream, meaning the same amount of R&D expenses makes more and more efficiency progress. In 2009, Suntech Power commenced commercial shipment of PV modules based on Pluto technology, a high efficiency PV technology achieving conversion efficiency rates in the range of 18.8% to 19.1% on PV cells manufactured with monocrystalline silicon wafers and 16.6% to 17.5% on PV cells manufactured with

[4] http://www.suntech-power.com/

multicrystalline silicon wafers. Suntech Power had achieved 450MW of Pluto enabled cell production capacity by December 31, 2010 based on Suntech annual reports. Despite this technology breakthrough, Suntech Power still diversified its R&D portfolio including thin film, plasmonic PV and organic cell technology to mitigate the threat of disruption.

2) Technology Adoption Life Cycle

Conventional crystalline PV technology still dominated market share in 2010. Suntech Power's market share remained 7% in 2009 and 2010 based on Suntech annual reports. Since the conversion efficiency of its Pluto technology is one of the highest among other module technologies and the cost gap between Suntech Power's Pluto modules and First Solar's thin film modules keep decreasing, Suntech Power was viewed as being very likely to be able to lead the solar industry to cross the chasm ahead of any other PV companies as long as it maintains its cost reduction strategy to reach grid parity and high momentum of technology improvement.

3) Economies of Scale

Suntech Power's annual production increased every year and the average selling price per watt declined from \$3.89 in 2008 to \$2.40 in 2009 to \$1.82 in 2010 based on Suntech annual reports. However, economies of scale of conventional crystalline PV are affected by the silicon price. The main sources of cost reduction were not from economies of scale, but from both efficiency improvement and silicon price decline as a result of oversupply.

Value Capture

1) Six Forces Analysis

According to REN21 reports, the top 15 PV manufacturers accounted for nearly 65% of market share in 2009; while in 2010, it dropped to 55%, indicating intensified competition from new entrants. Luckily, for Suntech Power, the market share remained 7%. Suntech Power has business relationships with over 50 suppliers of polysilicon and silicon wafers, procuring a significant portion of supplies under fixed price contracts, and remaining supplies from short-term supply agreements and the spot market. Since 2010, Suntech Power also began to manufacture silicon wafers, so the risk from suppliers for Suntech Power is relatively smaller than other crystalline PV companies. During 2010, sales to Suntech Power's largest customer, top three, and top 10 customers accounted for 6.5%, 14.5% and 31.8% of total net revenue, respectively based on Suntech annual reports. Suntech would continue diversifying customer concentration to capture value from new regional markets with strong demand for PV products, including the United States, Japan, China, and South East Asia, emerging Europe, and Africa, which would further reduce the bargaining power from buyers.

2) Value Chain

After the silicon price decline of 2009, the incentive of upward integration to reduce costs and secure supply for crystalline silicon PV manufacturers was no longer a factor. Nevertheless, in the fourth quarter of 2010, Suntech Power joined wafer production by acquiring Rietech, a spin off from Glory Silicon, Rietech is a Chinese-based silicon ingot and wafer manufacturing facility with 375MW of capacity. This movement not only reduced the material cost, but, most importantly, achieved the integration of wafer, cell and module design and production to further reduce the process costs and the conversion efficiency. In addition, in 2006, Suntech Power focused more on downstream operations by acquiring Suntech Japan (formerly MSK), a leading manufacturer of BIPV systems based in Japan, and, in 2008, EI Solutions, Inc., a commercial PV systems integration company based in the United States, now part of Suntech America. Suntech Power also invested in Global Solar Fund, S.C.A, Sicar, or GSF, an investment fund created to make investments in private companies that own or develop projects in the solar energy sector.

3) Unique Assets and Complementary Assets

Suntech's unique asset was the high efficiency Pluto PV technology which reached 19% conversion efficiency in for mono-crystalline cells 2010 based on Suntech annual reports. As for complementary assets, Suntech Power acquired KSL-Kuttler Automation Systems GmbH, or KSL-Kuttler, a leading Germany-based manufacturer of automation systems for the printed circuit board industry, and CSG Solar AG, or CSG Solar, a German company involved in developing, producing and marketing PV cells on the basis of crystalline silicon on glass technology. Both

acquisitions would help Suntech Power to further reduce module costs and capture value in the long run.

Value Delivery

1) Simple Rules, Regenerating, and Probing

Suntech Power's goal was to achieve retail grid parity in 50% of global markets by 2015. The means of doing with was to reduce the cost of solar energy through raising the performance of solar cells and panels on readily available substrates rather than break the efficiency barrier with rare metals and expensive manufacturing processes according to Suntech reports. To achieve this target, Suntech Power acquired an automation system and glass technology to enhance its core technology, instead of adopting a totally different technology, expanded production of the high efficiency Pluto technology, leveraged wafer production to drive down cost, and continued to invest in brand name and global sales network. Suntech also conducted the majority of its development, design and manufacturing operations in China, where the costs of skilled labor, engineering and technical resources, as well as land, facilities and utilities, tend to be lower than those in more developed countries. In order to further increase operating efficiencies and expand manufacturing capacity in a cost effective manner, Suntech balanced automation and manual operations in our manufacturing processes. By following these rules, Suntech Power successfully delivered value and became market leader in 2010.

2) Timing Pacing

Suntech Power successfully managed transitions from the EU market to other markets such as the U.S. and Chinese markets in recent years. About 50% of estimated revenue would be from Europe in 2011, decreased from 77.7% in 2008. In contrast, revenue from the U.S. increased from 7.4% in 2008, to 20% estimated revenue in 2011, which is 5% higher than the global market average in Q3 2011. Suntech Power adopted a vertical integration strategy to drive down costs to transit from subsidized markets to non-subsidized markets. Suntech Power, like First Solar, also adopted event pacing strategy and adjusted its capacity plan in response to events such as the global financial crisis. As a result, Suntech did not gain market share in 2010. In response to this intensified competition, Suntech Power even planned to hold capacity at current levels in 2012 to minimize capital expenditures. It was envisioned that if Suntech Power could follow a time pacing strategy and find the right rhythm to expand production lines according to the calendar, it might be able to keep its market leadership.

Case Three: Solyndra

Solyndra, founded in California in 2005, was a cylindrical CIGS thin-film solar module manufacturer. The company opened its second plant, Fab 2, a new state-of-the-art robotic facility in Fremont, California in 2010 at a cost of $733 million with the support of a $535 million federal loan guarantee. However, it went bankrupt in 2011 (Datla et al., 2012).

Value Creation

1) Technology S-curve

Unlike traditional flat panels, Solyndra produced panels made of racks of cylindrical tubes. Solyndra rolled its copper-indium-gallium-diselenide (CIGS) thin films into a cylindrical shape which could absorb both direct and diffuse sunlight. Although the high-end 210 panel had a field efficiency of only 8.5% calculated by Solyndra's product specification, the technology still had great potential to grow.

2) Technology Adoption Life Cycle

When Solyndra was first launched, thin film technology was growing year by year. However, as previous analysis has shown, thin film market share started to decline in 2009. The conversion efficiency of Solyndra's new cylindrical CIGS thin film technology wass substantially lower than crystalline silicon PV technologies and even lower than existing thin film technology, and the scale and cost gap between Solyndra and other companies steadily increased due to the decrease in the silicon price. As a result, Solyndra's technology became more and more unlikely to cross the chasm. Another issue was that Solyndra claimed lower installation costs and better levelized cost of electricity. For a new technology with high capital costs, it was very difficult to be successful.

3) Economies of Scale

In thin film industry, economies of scale could be a more important factor for cost reductions than

saving raw material costs because the raw material costs are relatively less than they are for crystalline silicon modules. In addition, installation costs were for Solydra modules was cheaper than for crystalline silicon modules because Solydra modules could sit flat and be packed tightly on commercial rooftops. However, dispite the potential advantage, Solydra closed its old factory, called Fab 1, laid off around 40 employees and did not renew contracts for about 150 temporary workers in order to save the company $60 million in capital expenditures. The movement marked the beginning of Solyndra's failure.

Value Capture

1) Six Forces Analysis

Solyndra tried to capture value and avoid price competition by fitting in a niche, roof top solar system, and consolidating relationships with about 38 solution providers. However, the radical change of solar industry due to the dramatic price decline of crystalline PV module created cost advantages for the existing crystalline silicon module manufactures, particularly those in China, and further reduced the value that Solyndra could capture. New entrants with low cost modules posed a great threat to Solyndra.

2) Value Chain

Solyndra suffered from the established solar companies' vertical integration strategy to capture value from U.S. market with low cost modules as a result of ramped up production.

3) Unique Assets and Complementary Assets

Solyndra's unique asset was the brand new cylindrical CIGS thin film technology. However, Solyndra failed to develop complementary assets fast enough to lower the higher cost of manufacturing its high-tech modules.

Value Delivery

1) Simple Rules, Regenerating, and Probing

"Clean and Economical Solar Power from Your Large Rooftop," was the slogan written on the front page of Solyndra's now non-existent website. Solyndra's cylindrical technology was designed for the rooftop and is supposed to offer the benefits of light weight, low cost and the fastest, easiest installation of any solar technology. However, failing to achieve this low cost led to Solyndra's demise.

2) Timing Pacing

Solyndra delivered $100 million of revenue in 2009, and $140 million in 2010, but it failed to lower its costs fast enough by leveraging economies of scale to transit subsidized markets to non-subsidized markets. Solyndra, like First Solar and Suntech, also adopted event pacing strategy and adjusted its capacity plan in response to events such as intensified cost competition. As a result, Solyndra went bankrupt. A time pacing strategy might have yielded a different result in this fast changing solar industry.

Case Four: Vestas

Vestas[5], headquartered in Denmark and founded in 1945, is the world's largest wind turbine manufacturer. In 2010 the company was shipping to 63 countries around the world with cumulative installation of more than 41,000 turbines and 22,000 employees globally. It has production facilities in more than 12 countries and is further expanding its facilities to other countries, such as China, Spain and the United States (Steenburgh and Corsi, 2011).

Value Creation

1) Technology S-curve

According to FIG. 2, the wind technology has potential to further increase kWh per dollar, given abundant R&D investment. Vestas was aware of this trend and increased the number of R&D employees in 2010 by more than 50%, with R&D expenses increasing from 249 to 372 million Euros , the equivalent of an increase of nearly 10 kWh per dollar. At the same time, Vestas actively collaborated with leading universities and other research-intensive educational institutions in order to retain its technological industry leadership position.

2) Technology Adoption Life Cycle

Based on previous analysis, the wind industry has crossed the chasm. Therefore, Vestas has penetrated early majority and is trying to reach late majority by constant quality improvement, intact customer service support, and regionalization. Vestas currently has installed capacity in 67 countries. Vestas has also built manufacturing

[5] http://www.vestas.com/

plants in high demand countries such as U.S. and China to reduce transportation costs and cater to local needs. The goal is to produce 80-90 per cent of a Vestas turbine locally, including components from suppliers.

3) Economies of Scale

Vestas currently enjoys economies of scale since its scale is the largest in the wind industry. The next target is to maintain headcount rise at a lower rate, while business volume grows, especially in new factory capacity. This strategy could make Vestas more cost effective.

Value Capture

1) Six Forces Analysis

The bargaining power of suppliers is not an issue for Vestas, because it produces most its components and parts in-house except for gearboxes which are supplied by independent manufacturers. Vestas has in 2010 had 212 customers and very high customer loyalty due to its high quality products and world renowned customer service. The biggest threat is from low cost Chinese rivals such as Sinovel andGoldwind. If Vestas wants to capture value in China, it must compete with these local businesses supported by the Chinese government. Without hesitation, Vestas opened the Technology R&D Center in China in October 2011 to attract local talents and provide customized wind energy solution in the fast growing Chinese market.

2) Value Chain

In the wind industry, the value chain goes from component suppliers, wind turbine manufacturers, wind farm developers to primarily electric utilities. Vestas defines itself as a wind energy solution provider capable of delivering both wind turbines and wind power systems. Vestas implemented Six Sigma in 2005 not only in its factories but also in suppliers' factories. This strategy required close relationships with suppliers and will improve the quality, reduce the overall costs, and shorten the delivery time. Given the close collaboration with suppliers, Vestas planned to build wind turbines from easily accessible and renewable materials which can further reduce its sensitivity to unstable raw materials prices and materials that are hard to access.

3) Unique Assets and Complementary Assets

Vestas' V112-3.0 MW turbine was awarded the "Most Innovative Power Technology of the Year" in the 2010 Asian Power Awards held in Singapore on November 3, 2010. The turbine has a blade profile that was new, nacelle design and cooling-system that delivered load-optimized operation with the new GridStreamer technology, which delivers high, stable plant output complying with the most stringent grid requirements worldwide.

Other than complementary assets such as broad sales channels and good relationships with politicians, Vestas focused its efforts on creating the world's strongest energy brand. It paid attention to waste management and conducted wind turbine life cycle analysis to reduce the environmental impact as much as possible. All these practices helped Vestas build positive social image. In addition, Vestas launched SiteHunt service to help customers evaluate potential sites and SiteDesign service to optimize the layout of wind power plants.

Value Delivery

1) Simple Rules, Regenerating, and Probing

Vestas' strategy is intended to achieve world class safety standards at all Vestas locations, and have the most satisfied customers, the best performing wind power plants and the most environment-friendly production. Following this strategy, Vestas implemented a rule, called Triple15, translating into "no later than in 2015", which obligates Vestas to achieve an EBIT margin of 15% and a revenue of 15 billion Euros. This rule guided its direction to lower costs, invest directly toward intangible assets, and at the same time increase revenue. To lower costs, Vestas strives to achieve a high degree of capacity utilization, more efficient use of resources, and even roll out a new organizational set-up in 2012.

2) Timing Pacing

Vestas has a slogan for making transitions from the EU market to other markets such as the U.S. and Chinese markets, "In the region, for the region." By transferring production from Europe to the U.S. and China, Vestas not only smoothly transitioned to these countries, but also lowered manufacturing costs and reduced transport needs. Furthermore, Vestas would use rail transportation to save

transportation costs and reduce CO2 emissions.

The wind industry is relatively stable compared to the solar industry. Therefore, event pacing strategy could be suitable. However, in some fast growing markets, Vestas should adopt time pacing strategy to secure the market share. Nevertheless, Vestas follows the strategy of prioritizing customers and quality rather than turbine price and market share. As a result, Vestas' market share decreased from 19.8% in 2008 based on BTM reports to 14.3% in 2010 based on REN21 reports. In 2012, Vestas had 14% of the market share and GE had 15.5%

Case Five: Suzlon

Suzlon[6], founded in 1995, is the largest wind energy company in India in terms of market share and the 6th worldwide in 2010, with accumulated installation of 17 GW and 13,000 employees around the world in 2010 according to Suzlon annual reports.

Value Creation

1) Technology S-curve

Despite the great potential of wind technology S-curve, Suzlon decreased 50% of its R&D expenditure in 2010 as a result of required cost savings. Besides, Vestas was hesitant to invest in a potentially disruptive technology, gearless direct drive turbines, which was seen as likely to take over traditional drive train turbines. Whether Suzlon stays competitive and innovative is unclear.

2) Technology Adoption Life Cycle

To further penetrate early majority and reach late majority, Suzlon improved customer services, and adopted both cost leadership and differentiation strategies. The practices include: opening a new 66,000 sq. ft. facility in Chicago, Illinois which is the hub for pre-planned logistics across the US. Suzlon also utilized its five Suzlon Monitoring Centres (SMC) across the globe to collect data on power output and system performance for customers to check the current status and performance of their assets. As a result, Suzlon took the second place among all the established manufacturers in an annual service survey in 2010 conducted by the German Wind Energy Association (BWE)[7].

3) Economies of Scale

Suzlon has enjoyed economies of scale. However, Suzlon's low costs were mainly due to the low labor costs. When the wind industry just started to launch production in India and China, Suzlon had already created value from its well-developed low cost supply chain in these low-cost countries.

Value Capture

1) Six Forces Analysis

Similar to Vestas, Suzlon produces most of the components and parts in-house to reduce the bargaining power of suppliers. To reduce the bargaining power of customers and have access to Europe market, Suzlon acquired REpower, a multi-megawatt wind turbine and offshore wind technology provider. Suzlon's product portfolio increased right away. Suzlon knew that cost advantage alone was not enough to compete with low cost Chinese rivals. Technology and services are the keys. Therefore, Suzlon opened factories and R&D center in China. If Suzlon failed to maintain its' technology superiority and keep driving down costs, it would not be able to capture value in Chinese market.

2) Value Chain

Suzlon adopted an upstream integration strategy to mitigate the risk of increase in commodity prices and shortage of critical components. Suzlon even produced gearboxes in-house through its acquisition of Hansen Transmission International, a cutting-edge gearbox manufacturer. However, due to a shortage of cash flow, Suzlon disposed of Hansen Transmission International in 2011 and lost the supply chain advantage afterwards. Regardless of the lost, Suzlon's Global Learning and Development Program trained 80 representatives from 50 suppliers on the Production Part Approval Process (PPAP) during the years of 2010 and 2011.

3) Unique Assets and Complementary Assets

Suzlon has a wide range of products ranging from 600 kW onshore wind turbines to 6.15 MW offshore wind turbines. In terms of offshore wind technology, REpower, Suzlon's subsidiary, is one of the tops in wind industry. Low cost labor constitutes the main part of Suzlon's complementary assets, enabling Suzlon to be one of the most cost effective companies in wind industry. The next challenge for Suzlon would be to capture

[6] http://www.suzlon.com/
[7] http://www.wind-energie.de/en

value in the emerging market. The answer might be by leveraging its low cost supply chain globally or strengthening its offshore wind technology capabilities.

Value Delivery

1) Simple Rules, Regenerating, and Probing

One of Suzlon's rules was to be in the top three wind companies in all the key markets of the world. However, due to finacial constraints, Suzlon was not able to expand fast enough to achieve the target quickly. Another rule was to be the technology leader in the wind sector. Ironically, Suzlon cut its R&D expenditures in 2011 by 50%. With reduction in investments in technology, it could be more difficult for Suzlon to be a technology leader.

2) Time Pacing

It's relatively easier for Sulzon to make transitions from the EU market to India, because Suzlon is based in India, one of the emerging markets. Suzlon has been the market leader in India until now for 13 years. Suzlon also did well in Brazil, with the biggest market share in 2009. As for the U.S. market and Chinese markets, Suzlon needs to spend more time and effort to grow its presence.

Suzlon, like most of other companies in wind industry, adopted an event pacing strategy, waiting to respond to opportunities instead of creating them. Without a time pacing strategy, Sulzon's market share is shrinking and production capacity is growing slow.

Conclusions

What Are the Effective Technology Strategies to Create Value in Solar and Wind Renewable Energy Industries?

Solar and wind energy deployment barriers which include high capital cost and slow asset turnover; incumbent advantage; commodity status of energy; reliability premium; regulatory environment; technology risks; and policy, regulatory, and market uncertainties. To grow, these industries need strong government support in terms of both R&D funding and policy incentives until they cross the chasm, especially the solar industry.

For thin film PV companies, economies of scale could be an essential factor for cost reductions rather than striving for savings in raw material costs because the raw material costs are much less than they are for crystalline silicon modules. Thin film PV companies with potentially disruptive technologies could make more efforts on R&D to leverage the phase of accelerated improvement on the technology S-curve. Traditional crystalline silicon PV companies should pay attention to mitigate the threat of disruptive technologies and secure value creation in the long run. Overall, cost reduction is the key factor to cross the chasm in solar industry.

Wind companies should look towards offshore wind as a potentially strong market and at the same time pay attention to emerging technologies. Wind companies could penetrate the early majority and reach the late majority by going global and at the same time securing local markets.

What Are The Effective Technology Strategies To Capture Value In Solar And Wind Renewable Energy Industries?

As the competition intensifies both in solar and wind industries due to the low cost Chinese entrants, solar and wind companies have to focus on cost reductions by all means. For crystalline solar module companies, upstream vertical integration is currently not necessary to reduce material costs due to the oversupply of silicon. Downstream vertical integration to be an energy solution provider is a trend in the solar industry because it can secure the project pipeline and minimize the BOS costs.

Achieving a diverse market portfolio is the long term solution to capture value both in solar and wind industries. Solar and wind companies should leverage existing complementary assets to enter emerging markets to achieve global presence.

What Are the Effective Technology Strategies to Deliver Value in Solar and Wind Renewable Energy Industries?

The most useful simple rule in today's solar and wind industries is "reducing cost in any possible way." In the solar industry, companies should strive to reach grid parity to make transitions from subsidized markets to non-subsidized markets. Despite the uncertain market conditions, innovation via R&D could lead to long term value delivery. Setting a time pace to reduce costs is a more effective strategy than blindly increasing capacity given the highly uncertain market condition both in the solar and wind

industries.

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